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Assessment of ATC wind reports - case studies at Heathrow.

by M. J. O. Dutton

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ASSESSMENT OF ATC WIND REPORTS - CASE STUDIES AT HEATHROW

(by M.J.O. Dutton)

1. Introduction

On six occasions during summer 1979 comparisons were made, for 50 flights, between the wind supplied by Heathrow Air Traffic Control (ATC) to pilots shortly before take-off and landing and the wind (at the anemometer) at the time of take-off or landing. For each period selected for study the distributions of these differences, or errors, are presented in this note, together with, for comparison, the distributions that would have resulted if the wind report had been the latest automatically computed 30-second, 1-minute or 2-minute average.

2. The data

2.1 ATC Voice cassettes For each case study the following basic arrival/departure information was extracted from the cassettes (for 50 flights):-

(i) aircraft call-sign

(ii) Final wind passed by ATC

(iii) Time (hr/min/sec) final wind passed

(iv) Time (hr/min/sec) aircraft declared 'airborne' or 'landed'.

It was assumed that the voice cassette clock was accurate to within ten seconds and that the wind directions passed by ATC were in degrees magnetic ($\equiv$ degrees true + 7°). In all the case studies, winds from the NE-site anemometer were used by ATC. (On each occasion, this was obvious from an initial cursory comparison of ATC winds with the wind information recorded at the NE-site and SW-site). Data from the NE-site was therefore used for the 30-sec, 1-min and 2-min averages.

Some difficulty arises in attempting to fix the precise time of touch-down or lift-off; it appears that touch-down or lift-off occurs some (variable) time before ATC actually declare 'landed' or 'airborne'. For the purposes of the case studies looked at in this note, touch-down (lift-off) was assumed to have occurred 15 seconds before ATC declared 'landed' ('airborne'); it is worth noting however that the results of the comparisons described in section 4 remain substantially unchanged if a delay time of 30 seconds is used instead of 15 seconds.

If, as occasionally happened, the pilot declared 'rolling' immediately after receiving the final wind report, take-off time was assumed to be 30 seconds later; here again, a value of 45 seconds rather than 30 seconds does not materially affect the results.

2.2 DALE wind information Two Digital Anemograph Logging Equipment (DALE) units continuously logged 30-second averages of surface wind at both Heathrow anemometer sites. For each arrival/departure logged from the voice-cassette data, the appropriate 30-second, 1-min and 2-min winds were extracted/computed from the NE-site DALE records. The timing associated with these records was known to be within ten seconds of GMT.

3. The Analysis

In each of the six case studies, the following ('forecast') winds for fifty flights were each compared with the relevant 30-second wind* centred on the time of touch-down or lift-off ('actual' wind):-

(i) Final ATC wind
(ii) 2-min wind
(iii) 1-min wind
(iv) 30-second wind

} 'forecast' winds

The first part of the computer program output for each case study (Tables 1a, 2a, ... 6a) contains a list of the 50 arrivals/departures sampled. This included :-

(i) Date - (year/month/day)
(ii) Time (GMT) - time of touch-down or lift-off (hour/min/sec)
(iii) Lag - time lag between supply of final wind and touch-down or lift-off (min/sec)
(iv) ATC wind - wind direction corrected to degrees true (degrees/knots)
(v) 2-min wind
(vi) 1-min wind
(vii) 30-second wind

} time average of wind up to time final ATC wind passed (degrees/knots)

(viii) 'Actual' wind - 30-sec wind centred on time of touch-down or lift-off (degrees/knots)

The computer program computes the following for each take-off and landing:-

(i) Magnitude of the vector error in 'forecast' wind ('forecast' minus 'actual').
(ii) along-runway component 'forecast' error (positive values indicate an overforecast headwind).
(iii) across-runway component 'forecast' error (positive values indicate an overforecast left crosswind)

The mean vector error and its standard (vector) deviation are also computed, and the second part of the program output (Tables 1b, 2b, ... 6b) contain these basic statistics together with the frequency distributions of vector error magnitudes (in ranges 0 to 1, 1 to 2, ... 19 to 20, > 20 kt), and of along-runway component errors (in ranges < -10, -10 to -9, ...8 to 9, 9 to 10,

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* Typically a 30-second wind average at a fixed point would affect an aircraft flying into the wind direction for about 5 seconds.

> 10 kt). In addition the vector mean wind and its standard vector deviation, the mean wind speed, mean E–W and N–S components and their standard deviations are all computed for the period covered by the 50–flight sample.

4. Results

4.1 Case study 1: 0700 – 0816 GMT, 25/6/79 (Tables 1a, 1b)

This period was selected for an initial 'pilot' study. The results are not particularly interesting since the wind remained relatively light and steady throughout the period (mean wind 200/8 kt, standard vector deviation 2.2 kt); the 50 flights sampled used runways 28L (10 arrivals) and 28R (40 departures). There was only one vector error greater than 5 kt (ATC wind for flight no. 20). However, it is perhaps interesting to note that the mean vector error in the ATC wind (2.8 kt) is double that of the 2–min wind (1.4 kt). The superior performance of the 30–sec, 1–min and 2–min averages is obvious, although on this particular occasion the vast majority of errors were almost certainly too small to be of any consequence. A particular feature of the winds passed by ATC was that the wind speed was almost exclusively given as "10 kt" throughout the period.

4.2 Case study 2: 1200 – 1252 GMT 9/8/79 (Tables 2a, 2b)

This period was one of strong and gusty west–north–westerly winds (mean wind 290/23 kt, standard vector deviation 3.9 kt) and a number of large errors were anticipated; the DALE 30–second wind series during the period is shown in Figure 1. The 50 flights sampled used runways 28L (25 arrivals) and 28R (25 departures). Again the superiority of the time–averaged winds (2–min, 1–min, 30–sec) is obvious. Half (25) of the ATC reports contained vector errors in excess of 5 kt, 3 of these being in excess of 10 kt (flight nos. 9, 33, 35). The number of vector errors > 5 kt is halved by using a time average, and the errors > 10 kt are eliminated. Looking at the ATC errors in along–runway component, 12 are outside ±5 kt (2 of which are greater than 10 kt) and all of these involve overforecasts of the strength of the headwind component. This figure (12) reduces to 7 for the 2–min wind, 4 for the 1–min wind and 5 for the 30–sec wind. The error distributions for the across–runway component also militate strongly in favour of the use of a standard time average: 9 ATC errors outside ±5 kt compare with only one for the time–averaged winds.

4.3 Case study 3: 1100 – 1150 GMT 14/8/79 (Tables 3a, 3b)

This was a period of strong and gusty south–south–westerly winds, giving a substantial cross–runway component to movements on runways 28L and 28R (mean wind 220/23 kt, standard vector deviation 4.6 kt); the DALE 30–second wind series during the period is shown in Fig 2. The sample includes 25 landings on runway 28L and 25 take–offs from 28R. Particularly disturbing here is the high number

(9) of ATC vector wind errors in excess of 10 kt. The flight numbers involved (2, 20, 22, 25, 31, 35, 43, 47, 50) were all landings, except one (no 43). The use of a 2-min or 1-min average eliminates all of these large errors, while the use of a 30-sec average reduces the number to one. The use of a 2-min average minimises the number of along-runway component errors outside ±5 kt, while the 30-sec, 1-min and 2-min winds all perform similarly in substantially reducing the number of across-runway component errors in the ATC wind.

4.4 Case study 4: 0830 - 1020 GMT 26/11/79 (Tables 4a, 4b)

The mean wind on this occasion was 230/17 kt (standard vector deviation 3.6 kt) at the NE-site and the results are broadly similar to those in case studies 2 and 3. The sample of 50 flights is made up exclusively of arrivals on runway 23 (oriented 222 deg True). A total of 20 ATC vector errors in excess of 5kt is reduced to, respectively, 8, 7 and 11 with the use of 2-min, 1-min and 30-sec averages. The substantial positive bias in the ATC along-runway error component (ie headwind systematically overforecast) is largely due to the Controller's systematic tendency during this period to overforecast the wind speed by about 3kt on average. (This tendency was also evident, to a lesser degree, in case study 2). Of the time-averaged winds, the 1-min and 2-min values show equal merit, both performing marginally better than the 30-second average.

4.5 Case study 5: 1000 - 1150 GMT 5/12/79 (Tables 5a, 5b)

This was another occasion of moderate/strong south-south-westerly winds (mean wind 220/18 kt, standard vector deviation 3.0 kt), and, again, the sample is made up of 50 landings on runway 23. The results resemble those in case study 4. A total of 25 ATC vector errors in excess of 5 kt (one of which, for flight no 4, exceeds 10 kt) reduces to, respectively, 4, 4 and 2 with the use of 2-min, 1-min and 30-sec averages. There is, again, an appreciable positive bias in the ATC along-runway error component, due to systematic overforecasting of the wind speed, by about 4 kt on average on this occasion (mean ATC-supplied wind was 220/22 kt). In this case study the performances of the 2-min, 1-min and 30-sec averages do not differ significantly.

4.6 Case study 6: 1900 - 2055 GMT 9/12/79 (Tables 6a, 6b)

This case study covered a period of moderate/strong south-south-westerly to westerly winds (mean wind 230/18 kt, standard vector deviation 10.9 kt) but, as the large value of standard vector deviation suggests, it is characterised by a wide variation in the mean wind (direction 200 - 270 deg, speed 10 - 45 kt) during the period as an active cold front passed through Heathrow just after 1940 GMT. (See Fig 3). A further interesting point is that, up to about 1955 the wind at the SW-site (pecked lines in Fig 3) differed systematically from that at the NE-site, the wind speed at the SW-site being about 5 kt lighter on average and the wind direction being about 10 degrees veered relative to the

NE-site wind. Note, in particular, that the brief period of very strong winds (35 - 45 kt, maximum gust 55 kt) at the NE-site between 1942 and 1945 was not experienced at the SW-site where, incidentally, the cold front passed through about 2-minutes before it reached the NE-site.

Due to problems with the quality of the voice-cassettes for this case, only 48 movements were sampled. These comprised:-

	28R	28L	23
Take-offs	18	7	0
Landings	6	4	13

It was stated in section 2.1 that ATC used winds from the NE-site for all the occasions covered in this note, and this was certainly true for 41 of the 48 movements here; but there is some doubt as to which anemometer was used for the 7 take-offs on runway 28L (2034 - 2052 GMT). However this uncertainty assumes little importance, as the winds at the two sites were very similar (about 240/15 kt) during that period and, for computational convenience, the winds from the NE-site were used to derive the appropriate averaged winds.

The superior performance of the time-averaged winds here is not as conclusive as it was in case studies 2-5. A total of 5 ATC vector errors $>$ 10 kt reduces to 3, 2 and nil for the 2-min, 1-min and 30-sec winds respectively. The 3 large vector errors in the 2-min wind all occurred between 1941 and 1945 (flight nos. 24, 26, 27), as did the two largest 1-min vector errors (flight nos. 24, 27); this highlights perhaps the only shortcoming of the (linearly) time-averaged wind, its inability to react sufficiently rapidly to very abrupt changes in the wind (the longer the averaging time, the slower the response). This problem can, however, be largely overcome by adopting a time-average which is weighted progressively more heavily towards the most recent past, rather than one which, as in these case studies, gives equal weight to all the winds within the averaging time (e.g. the 2-min average is calculated by giving equal weight to each of the constituent 30-sec averages).

It is interesting to note that flight no. 26 (landing on 23 at 1943:33) was passed a wind of 220/55 (equivalent to the maximum gust recorded) at 1942:36, this being updated 18 seconds later (39 seconds before touchdown) to 220/40; the 'actual' wind turned out to be 225/42.5, so that for this particular aircraft the ATC wind proved to be more accurate than any of the time-averaged values.

The effects of the large wind variations between 1940 and 1945 GMT did not go unnoticed by pilots: flight no. 25 (take-off on 28R at 1941:43) reported "buffet at 800 feet" while flight no. 26 (mentioned above), landing two minutes later on 23, reported "severe turbulence at 200 feet". Between 1942 and 1946, much of the RT exchanges were with flight no. 29 (departure) who was not happy

about using 28R with winds of 220/50 (he declared his crosswind limit as 25 kt). Asked if he could wait for a gap between landings on 23, he said he would "rather have a gap in the wind". This is indicative of a poor understanding of wind variability and the limitations of ATC wind reports, especially in such turbulent conditions. Eventually declaring that he would accept a wind of 220/44 on 28R (giving a crosswind of 37 kt!), he hesitated between 23 and 28R, but as the wind veered to 260, was quite happy and went off on 28R (at 1949:08). An incident involving flight no. 7 (landing on 23 at 1912:59) who dropped his braking parachute on the runway, forced the following aircraft to overshoot when on short finals; the affected aircraft (flight no. 15) landed on 28L at 1927.34, nearly 15 minutes later.

5. Concluding remarks

Case studies 2 to 6 all involved moderate/strong wind situations which occur infrequently at Heathrow (mean wind > 20 kt about 1.5 per cent of the time), but these are just the situations in which many large errors in wind reports to pilots occur, due simply to the large time-variability of the surface wind in such conditions. Table 7 contains summarised information for case studies 2-6 combined (total of 248 movements sampled) and the figures speak for themselves. Overall, it is difficult to choose between the 2-min, 1-min and 30-sec averages.

Case study 1 showed that, in light and steady wind conditions, although very few errors of any consequence occur, the use of a time-averaged wind leads to a significant improvement in the accuracy of wind reports.

In conclusion, the results from this small sample strongly support the ICAO recommendation (Meteorological Services for International Air Navigation, 8th Edition (1976), Annex 3, Recommendation 4.5.5) for a standard averaging period for wind reports for take-off and landing; ICAO recommend a 2-min averaging period.

TABLE 1a

	DATE	TIME	LAG	ATC	2-MIN	1-MIN	30-SEC	ACTUAL	
1	790625	704.15	1.50	200/12	210/11	210/12	210/13	213.0/12.1	LAND
2	790625	705.35	1.20	200/12	210/12	210/12	210/12	215.0/12.0	LAND
3	790625	706.49	1.40	210/12	210/12	210/12	210/12	220.0/ 9.9	LAND
4	790625	708.20	1.00	200/10	220/10	220/10	220/10	203.0/11.0	T/O
5	790625	708.35	1.10	200/10	220/10	220/10	220/10	203.0/11.0	LAND
6	790625	710.35	1.05	200/10	210/ 9	200/ 9	200/ 8	226.0/ 8.9	LAND
7	790625	711.25	1.50	210/10	210/ 9	200/ 9	200/ 8	213.0/ 7.0	T/O
8	790625	712.45	1.30	200/10	210/ 8	220/ 8	210/ 7	211.0/ 9.0	LAND
9	790625	713.10	1.20	200/10	210/ 8	210/ 8	210/ 9	211.0/ 9.0	T/O
10	790625	715.13	2.08	190/10	210/ 9	210/ 9	210/ 9	214.0/ 8.9	T/O
11	790625	716.50	1.15	190/10	210/ 8	210/ 9	200/ 9	204.0/ 8.7	LAND
12	790625	717.09	1.35	190/10	210/ 8	210/ 9	200/ 9	204.0/ 8.7	T/O
13	790625	718.25	0.50	190/10	200/ 9	200/ 8	200/ 8	208.0/ 7.4	LAND
14	790625	719.45	1.45	190/10	200/ 8	200/ 8	200/ 7	200.0/ 8.9	T/O
15	790625	720.29	2.29	190/10	200/ 8	200/ 8	200/ 7	206.0/ 9.5	LAND
16	790625	721.45	0.55	190/10	210/ 9	210/ 9	210/ 9	215.0/ 9.9	LAND
17	790625	723.50	1.40	200/10	210/ 9	210/10	210/10	208.0/ 7.7	LAND
18	790625	725.40	1.25	200/10	210/ 8	210/ 8	220/ 8	215.0/ 7.4	LAND
19	790625	727.55	1.50	200/10	220/ 7	220/ 7	220/ 7	216.0/ 6.2	LAND
20	790625	728.43	1.43	210/10	210/ 7	210/ 7	210/ 8	221.0/ 5.1	T/O
21	790625	729.21	0.59	200/10	210/ 7	220/ 6	220/ 5	206.0/ 7.1	LAND
22	790625	731.05	1.10	190/ 8	210/ 7	200/ 7	200/ 8	201.0/ 9.1	T/O
23	790625	732.23	0.43	190/10	200/ 8	210/ 9	210/ 8	212.0/ 8.2	LAND
24	790625	732.45	1.33	190/10	200/ 8	200/ 8	200/ 9	211.0/ 7.6	LAND
25	790625	734.35	1.15	190/10	210/ 8	210/ 8	200/ 8	209.0/ 7.5	LAND
26	790625	735.05	1.55	190/10	210/ 8	210/ 8	210/ 8	208.0/ 7.3	T/O
27	790625	736.10	1.45	190/10	210/ 8	210/ 7	210/ 7	202.0/ 5.4	LAND
28	790625	736.40	1.35	190/10	210/ 7	210/ 7	210/ 7	205.0/ 7.3	T/O
29	790625	737.57	1.12	190/10	210/ 7	210/ 7	210/ 7	203.0/ 8.5	LAND
30	790625	739.30	0.53	190/10	200/ 8	200/ 8	200/ 8	204.0/ 8.2	LAND
31	790625	741.45	1.20	200/10	210/ 8	210/ 8	210/ 8	206.0/ 7.0	LAND
32	790625	744.00	1.00	190/10	210/ 8	210/ 8	210/ 8	209.0/ 8.0	LAND
33	790625	745.17	0.34	190/10	210/ 8	210/ 8	210/ 7	201.0/ 6.0	LAND
34	790625	747.10	2.00	200/10	210/ 7	210/ 7	200/ 7	197.0/ 7.0	LAND
35	790625	749.00	0.55	190/10	210/ 7	210/ 7	210/ 7	196.0/ 8.6	LAND
36	790625	750.57	1.07	190/10	200/ 8	190/ 8	190/ 7	189.0/ 8.7	LAND
37	790625	752.20	0.45	190/10	190/ 8	190/ 9	190/ 9	194.0/ 7.7	LAND
38	790625	753.57	0.47	200/10	190/ 8	190/ 8	190/ 8	188.0/ 8.0	LAND
39	790625	756.16	0.48	190/10	190/ 7	190/ 7	190/ 7	203.0/ 8.6	LAND
40	790625	758.15	1.07	190/10	200/ 8	200/ 8	200/ 8	187.0/ 9.3	LAND
41	790625	759.25	0.30	190/10	190/ 8	190/ 9	200/ 8	192.0/ 8.9	LAND
42	790625	800.55	1.55	180/10	190/ 8	190/ 9	200/ 8	191.0/ 7.6	LAND
43	790625	802.07	1.07	170/10	190/ 8	190/ 8	190/ 8	185.0/ 7.4	LAND
44	790625	803.50	1.38	190/10	190/ 8	180/ 7	180/ 7	197.0/ 8.9	LAND
45	790625	805.10	1.55	190/10	190/ 8	190/ 9	180/ 9	185.0/ 7.9	LAND
46	790625	806.50	2.10	180/10	190/ 9	190/ 8	180/ 8	184.0/ 9.7	LAND
47	790625	809.55	0.45	180/10	190/ 8	190/ 8	180/ 8	175.0/ 8.9	LAND
48	790625	811.45	1.15	180/ 8	180/ 8	180/ 8	190/ 8	174.0/ 6.3	LAND
49	790625	814.05	0.40	180/10	180/ 8	180/ 8	170/ 8	182.0/ 7.8	LAND
50	790625	815.32	0.30	180/ 8	180/ 8	180/ 8	180/ 8	177.0/ 7.1	LAND

	DATE	TIME	LAG	ATC	2-MIN	1-MIN	30-SEC	ACTUAL	

TABLE 16

HEATHROW ATC WINDS - CASE STUDY 1 DATE/TIME: 25/06/79 0700-0810 GMT

BASIC STATISTICS OF DIFFERENCES

	ATC WIND	2-MIN WIND	1-MIN WIND	30-SEC WIND
MEAN DIFFERENCE	2.8	1.4	1.5	1.6 KT
S.D. OF DIFFERENCE	1.1	0.8	0.9	0.9 KT

DISTRIBUTIONS OF WIND DIFFERENCES (OR ERRORS)

MAGNITUDE OF VECTOR ERROR (KT)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ATC	0	3	10	17	13	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-MIN	0	18	20	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-MIN	0	19	17	10	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-SEC	0	15	20	10	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ALONG-RUNWAY WIND COMPONENT ERROR (KT)

	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
ATC	0	0	0	0	0	0	0	2	8	14	14	8	3	1	0	0	0	0	0	0	0
2-MIN	0	0	0	0	0	0	0	0	1	7	13	20	6	3	0	0	0	0	0	0	0
1-MIN	0	0	0	0	0	0	0	1	2	4	13	21	6	3	0	0	0	0	0	0	0
30-SEC	0	0	0	0	0	0	0	1	2	5	18	15	6	3	0	0	0	0	0	0	0

ACROSS-RUNWAY WIND COMPONENT ERROR (KT)

	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
ATC	0	0	0	0	0	0	0	0	0	0	3	3	18	13	9	4	0	0	0	0	0
2-MIN	0	0	0	0	0	0	0	0	4	7	14	16	7	2	0	0	0	0	0	0	0
1-MIN	0	0	0	0	0	0	0	0	3	9	11	16	8	3	0	0	0	0	0	0	0
30-SEC	0	0	0	0	0	0	0	0	4	10	8	18	8	1	1	0	0	0	0	0	0

VECTOR MEAN WIND 201.9/ 8.0KT. STANDARD VECTOR DEVIATION 2.2KT.

MEAN WIND SPEED 8.3KT. COMPONENT MEAN -7.5KT (NS) -3.0KT (EW)

COMPONENT S.D. 1.2KT (NS) 1.8KT (EW)

TABLE 2a

	DATE	TIME	LAG	ATC	2-MIN	1-MIN	30-SEC	ACTUAL	
1	790809	1202.15	0.45	300/23	300/17	290/19	290/20	300.0/22.0	LAND
2	790809	1202.30	1.45	290/25	300/16	300/17	300/19	300.0/22.0	T/O
3	790809	1203.55	1.05	290/20	300/21	300/21	300/20	302.0/19.4	LAND
4	790809	1203.25	0.30	290/20	300/21	300/21	300/20	300.0/17.7	T/O
5	790809	1205.25	1.45	300/20	300/20	300/19	300/18	286.0/21.3	T/O
6	790809	1206.10	0.50	280/26	290/20	290/21	290/21	288.0/24.0	LAND
7	790809	1206.20	0.30	280/23	290/21	290/23	290/24	284.0/26.6	T/O
8	790809	1208.00	0.50	280/30	290/24	290/26	290/26	291.0/28.7	LAND
9	790809	1210.05	2.05	280/30	290/27	290/27	290/29	296.0/20.1	LAND
10	790809	1209.15	0.30	300/25	290/26	290/26	300/25	300.0/25.5	T/O
11	790809	1212.30	1.40	300/25	300/23	290/23	290/26	291.0/18.5	T/O
12	790809	1212.30	1.35	280/25	300/23	290/23	290/26	291.0/18.5	LAND
13	790809	1213.15	1.20	290/20	290/23	290/22	300/19	294.0/18.3	T/O
14	790809	1214.25	1.30	280/20	290/20	290/19	300/19	291.0/19.3	LAND
15	790809	1214.10	0.30	300/23	290/19	300/19	290/18	292.0/20.0	T/O
16	790809	1216.15	1.05	280/20	290/20	290/21	290/23	284.0/19.9	LAND
17	790809	1216.35	2.05	280/25	290/19	290/20	290/19	284.0/19.9	T/O
18	790809	1217.50	0.50	270/25	290/22	280/22	280/25	280.0/24.6	LAND
19	790809	1218.15	2.10	270/23	290/22	290/22	290/23	277.0/23.9	T/O
20	790809	1220.10	1.50	290/22	280/24	280/24	280/24	284.0/21.6	T/O
21	790809	1220.10	1.40	280/25	280/24	280/24	280/24	284.0/21.6	LAND
22	790809	1221.20	2.00	280/23	280/24	290/23	280/25	288.0/21.9	T/O
23	790809	1223.05	2.25	280/28	280/23	280/22	280/22	296.0/22.0	T/O
24	790809	1223.45	1.30	300/26	290/23	300/22	300/22	294.0/20.0	LAND
25	790809	1224.35	1.25	280/20	290/22	300/22	300/22	289.0/18.7	T/O
26	790809	1225.20	0.55	280/23	290/20	290/19	290/19	286.0/19.2	LAND
27	790809	1226.05	1.55	280/20	290/21	290/20	290/20	284.0/16.6	T/O
28	790809	1227.05	0.55	270/23	290/18	290/18	280/17	284.0/23.3	LAND
29	790809	1227.55	1.40	280/23	280/19	280/19	280/21	286.0/26.0	T/O
30	790809	1228.55	1.00	280/30	280/24	280/25	290/26	283.0/28.3	LAND
31	790809	1228.25	1.15	270/28	280/20	280/22	280/23	282.0/27.8	T/O
32	790809	1230.30	1.25	270/25	280/27	280/28	280/28	286.0/24.5	T/O
33	790809	1231.15	0.45	270/33	280/26	290/26	290/24	282.0/23.1	LAND
34	790809	1232.45	1.30	280/25	280/25	280/24	280/23	282.0/27.8	T/O
35	790809	1233.10	1.05	260/28	280/25	280/26	280/28	282.0/27.8	LAND
36	790809	1232.40	0.30	270/25	280/25	280/26	280/28	276.0/26.2	T/O
37	790809	1235.00	2.10	270/30	280/26	280/27	280/28	284.0/25.2	T/O
38	790809	1235.00	1.05	280/32	280/27	280/26	280/25	284.0/25.2	LAND
39	790809	1236.55	1.30	280/32	280/26	280/26	280/27	286.0/23.9	T/O
40	790809	1237.15	1.30	280/28	280/27	280/27	290/27	284.0/25.3	LAND
41	790809	1238.55	0.55	280/30	280/26	280/27	280/28	290.0/24.5	T/O
42	790809	1239.10	1.15	280/28	280/26	280/27	280/28	290.0/24.5	LAND
43	790809	1241.20	2.45	280/28	280/26	280/27	280/27	286.0/23.0	T/O
44	790809	1241.45	1.00	270/26	280/23	280/22	280/23	288.0/26.5	LAND
45	790809	1242.40	2.15	280/25	280/23	280/23	280/21	289.0/25.7	T/O
46	790809	1243.30	0.45	270/20	290/25	290/25	280/24	284.0/21.3	LAND
47	790809	1245.05	0.45	280/21	280/23	290/23	290/23	281.0/23.7	LAND
48	790809	1246.20	0.50	280/24	280/23	280/22	280/21	291.0/20.3	LAND
49	790809	1250.40	0.55	280/28	290/25	290/26	290/27	289.0/23.8	LAND
50	790809	1251.55	0.45	280/26	290/26	290/25	290/27	294.0/20.6	LAND

| | DATE | TIME | LAG | ATC | 2-MIN | 1-MIN | 30-SEC | ACTUAL | |

TABLE 2b

HEATHROW ATC WINDS - CASE STUDY 2 DATE/TIME: 09/08/79 1200-1252 GMT

BASIC STATISTICS OF DIFFERENCES

	ATC WIND	2-MIN WIND	1-MIN WIND	30-SEC WIND
MEAN DIFFERENCE	5.2	4.0	3.8	3.9 KT
S.D. OF DIFFERENCE	2.6	1.7	1.5	1.9 KT

DISTRIBUTIONS OF WIND DIFFERENCES (OR ERRORS)

MAGNITUDE OF VECTOR ERROR (KT)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ATC	0	1	2	6	9	7	11	2	5	3	1	1	1	1	0	0	0	0	0	0	0
2-MIN	0	2	5	9	8	14	7	2	3	0	0	0	0	0	0	0	0	0	0	0	0
1-MIN	0	1	5	12	8	13	8	1	2	0	0	0	0	0	0	0	0	0	0	0	0
30-SEC	0	4	2	10	11	10	7	3	2	0	1	0	0	0	0	0	0	0	0	0	0

ALONG-RUNWAY WIND COMPONENT ERROR (KT)

	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
ATC	0	0	0	0	0	0	0	2	3	1	4	8	5	5	4	6	4	2	3	1	0	2
2-MIN	0	0	0	1	2	2	3	4	3	3	3	3	2	15	6	1	1	0	1	0	0	0
1-MIN	0	0	0	0	1	2	3	4	4	4	4	3	6	10	3	5	0	0	1	0	0	0
30-SEC	0	0	0	0	0	1	4	4	4	4	5	6	5	6	3	4	0	1	2	0	1	0

ACROSS-RUNWAY WIND COMPONENT ERROR (KT)

	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
ATC	0	0	0	0	0	1	3	0	1	0	1	7	7	10	8	4	4	2	0	1	0	1
2-MIN	0	0	0	0	0	0	4	3	1	5	7	6	8	8	5	2	1	0	0	0	0	0
1-MIN	0	0	0	0	0	0	3	3	5	8	5	3	11	3	5	3	1	0	0	0	0	0
30-SEC	0	0	0	0	0	0	2	5	8	6	2	5	12	2	4	3	1	0	0	0	0	0

VECTOR MEAN WIND 287.4/ 23.0KT. STANDARD VECTOR DEVIATION 3.9KT.

MEAN WIND SPEED 23.7KT. COMPONENT MEAN 6.9KT (NS) -22.0KT (EW)

COMPONENT S.D. 2.1KT (NS) 3.3KT (EW)

TABLE 6

	DATE	TIME	LAG	ATC	2-MIN	1-MIN	30-SEC	ACTUAL	
1	790814	1102.05	0.15	220/26	210/24	220/25	220/25	218.0/25.7	T/C
2	790814	1103.20	1.35	210/30	220/24	220/25	220/25	218.0/19.4	LAND
3	790814	1103.20	0.45	220/25	220/25	220/24	220/23	218.0/19.4	T/C
4	790814	1105.15	1.00	230/18	220/23	230/25	230/26	229.0/21.8	LAND
5	790814	1105.45	2.00	220/25	220/22	220/22	220/24	219.0/19.2	T/C
6	790814	1106.20	1.35	230/25	230/24	230/25	230/25	223.0/21.2	T/C
7	790814	1108.25	1.20	210/28	220/23	220/25	210/27	223.0/21.8	LAND
8	790814	1108.55	1.25	220/25	220/23	220/25	210/27	223.0/21.8	T/C
9	790814	1109.40	0.45	210/30	220/24	220/22	220/21	227.0/27.8	LAND
10	790814	1111.43	1.25	220/30	220/23	220/22	220/21	225.0/25.8	LAND
11	790814	1113.15	1.10	230/28	230/24	220/25	220/24	225.0/27.4	LAND
12	790814	1113.55	1.45	230/25	230/24	220/25	220/24	223.0/24.4	T/C
13	790814	1114.35	1.10	210/28	230/26	230/27	220/27	230.0/26.6	LAND
14	790814	1115.30	1.10	230/25	230/26	230/25	230/27	210.0/20.2	T/C
15	790814	1116.05	0.50	210/25	220/22	220/19	210/20	212.0/21.1	LAND
16	790814	1116.45	0.30	220/25	220/19	220/18	220/15	213.0/20.2	T/C
17	790814	1118.40	1.25	220/25	210/19	210/20	210/19	215.0/23.8	T/C
18	790814	1118.45	1.00	200/25	210/20	210/22	210/24	217.0/24.4	LAND
19	790814	1120.05	2.05	220/25	210/20	210/22	210/24	210.0/22.8	T/C
20	790814	1120.25	1.10	200/28	210/23	210/22	210/20	227.0/21.7	LAND
21	790814	1120.40	1.10	220/25	210/23	210/22	210/20	227.0/21.7	T/C
22	790814	1122.02	1.07	220/18	220/22	230/22	230/22	239.0/22.2	LAND
23	790814	1123.00	1.25	230/20	230/23	230/23	230/24	221.0/20.3	T/C
24	790814	1123.40	1.10	230/20	230/22	240/22	230/21	214.0/22.1	T/C
25	790814	1125.07	1.32	200/35	230/21	220/21	210/22	222.0/28.4	LAND
26	790814	1125.30	0.50	220/25	210/27	220/30	220/28	222.0/26.2	T/C
27	790814	1126.57	1.07	200/28	220/28	230/25	230/24	220.0/24.7	LAND
28	790814	1128.17	0.47	210/25	220/24	220/26	210/27	210.0/25.0	LAND
29	790814	1128.45	1.40	210/25	220/24	220/22	220/25	213.0/21.3	T/C
30	790814	1129.50	1.30	210/25	220/24	220/25	220/24	215.0/15.6	T/C
31	790814	1129.55	1.05	200/22	210/24	210/23	210/21	227.0/20.9	LAND
32	790814	1130.50	0.50	220/25	220/20	230/21	240/22	235.0/24.6	T/C
33	790814	1132.15	1.15	230/25	230/21	240/23	230/25	215.0/19.5	LAND
34	790814	1132.40	1.35	230/25	230/21	240/23	230/25	215.0/19.5	T/C
35	790814	1133.55	1.15	200/25	230/22	220/19	210/19	230.0/18.4	LAND
36	790814	1134.45	1.45	220/25	220/22	210/21	210/23	217.0/29.1	T/C
37	790814	1135.40	1.35	220/25	220/20	220/19	230/18	215.0/25.4	LAND
38	790814	1136.00	1.15	210/30	220/23	220/27	220/29	217.0/27.6	LAND
39	790814	1137.25	0.40	210/30	220/27	220/28	210/30	221.0/23.5	LAND
40	790814	1137.55	1.40	220/30	220/27	220/26	220/25	220.0/22.6	T/C
41	790814	1138.55	1.50	220/25	220/27	220/28	210/30	228.0/25.6	T/C
42	790814	1139.50	1.05	210/25	220/23	230/23	230/26	225.0/18.7	LAND
43	790814	1140.30	2.05	230/30	220/24	220/22	230/21	236.0/19.6	T/C
44	790814	1141.35	0.55	230/22	230/21	230/19	240/20	230.0/18.7	LAND
45	790814	1142.50	1.55	220/25	230/19	230/19	230/18	219.0/18.7	T/C
46	790814	1142.55	0.45	220/15	230/19	230/18	230/18	219.0/18.7	LAND
47	790814	1144.25	1.05	200/22	220/18	220/19	210/19	229.0/23.1	LAND
48	790814	1145.35	3.40	220/20	230/19	230/18	230/18	232.0/26.0	T/C
49	790814	1146.20	1.20	210/30	220/22	220/23	220/24	210.0/26.3	LAND
50	790814	1149.35	1.25	200/30	210/27	210/28	210/25	220.0/26.2	LAND

DATE TIME LAG ATC 2-MIN 1-MIN 30-SEC ACTUAL

TABLE 3b

FEATHER ATC WINDS - CASE STUDY 3 DATE/TIME: 14/08/75 1100-1150 GMT

BASIC STATISTICS OF DIFFERENCES

	ATC WIND	2-MIN WIND	1-MIN WIND	30-SEC WIND
MEAN DIFFERENCE	6.6	4.8	4.7	5.2 KT
S.D. OF DIFFERENCE	3.4	2.0	2.5	2.5 KT

DISTRIBUTIONS OF WIND DIFFERENCES (OR ERRORS)

MAGNITUDE OF VECTOR ERROR (KT)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ATC	0	1	1	4	10	5	3	3	5	5	4	4	2	1	2	0	0	0	0	0	0
2-MIN	0	1	3	6	10	9	7	5	6	2	1	0	0	0	0	0	0	0	0	0	0
1-MIN	0	3	3	2	14	10	4	6	1	2	5	0	0	0	0	0	0	0	0	0	0
30-SEC	0	0	4	6	7	8	5	6	6	5	2	1	0	0	0	0	0	0	0	0	0

ALONG-RUNWAY WIND COMPONENT ERROR (KT)

	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
ATC	1	1	0	3	6	2	1	0	2	3	3	3	5	7	4	4	1	1	2	0	1	0
2-MIN	0	0	0	1	0	2	7	4	1	5	6	1	5	9	2	5	0	1	0	0	1	0
1-MIN	0	0	0	1	2	2	4	4	4	2	2	5	5	7	3	4	0	1	1	2	1	0
30-SEC	0	0	1	1	3	2	6	2	2	6	3	4	1	7	4	2	1	2	2	0	0	1

ACROSS-RUNWAY WIND COMPONENT ERROR (KT)

	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
ATC	0	0	0	0	0	2	1	1	1	5	5	3	1	3	6	5	3	1	3	6	0	4
2-MIN	0	0	0	1	1	2	2	4	8	4	5	1	5	3	7	1	4	1	1	0	0	0
1-MIN	0	0	0	1	1	3	3	2	5	6	7	2	4	3	6	4	2	1	0	0	0	0
30-SEC	0	1	0	0	0	1	3	4	6	1	4	5	8	6	5	1	1	0	2	2	0	0

VECTOR MEAN WIND 221.1/ 22.9KT. STANDARD VECTOR DEVIATION 4.6KT.

MEAN WIND SPEED 23.7KT. COMPONENT MEAN -17.3KT (NS) -15.0KT (EW)

COMPONENT S.D. 3.6KT (NS) 2.9KT (EW)

	DAT-	TIME	LA	ATC	2-MI	1-MI	30-SE	ACTUAL	
1	791	[illegible]	1.4	[illegible]	[illegible]	[illegible]	230/23	[illegible]	L
2	791	[illegible]	1.1	[illegible]	[illegible]	230/16	240/19	[illegible]	L
3	791	837.25	1.44	[illegible]	[illegible]	[illegible]	240/16	[illegible]	L
4	791	[illegible]	1.[illegible]	[illegible]	[illegible]	[illegible]	230/14	[illegible]	L
5	791	[illegible]	1.[illegible]	[illegible]	230/17	220/17	220/21	230.0/19.7	LA
6	791	841.29	1.[illegible]	[illegible]	230/19	240/17	240/16	[illegible]	LA
7	791126	843.30	2.[illegible]	[illegible]	230/15	230/14	230/14	[illegible]	LA
8	791126	845.35	1.1[illegible]	[illegible]	[illegible]	230/14	220/14	[illegible]	LA
9	791	[illegible]	[illegible]	[illegible]	230/19	230/21	230/21	[illegible]	L
10	791126	851.30	1.[illegible]	220/23	220/17	240/16	230/16	227.0/15.4	LA
11	791126	853.09	1.[illegible]	[illegible]	230/16	230/16	230/16	230.0/17.3	LA
12	791126	854.[illegible]	1.2[illegible]	[illegible]	230/17	230/16	230/15	[illegible]	LA
13	791126	858.20	1.22	240/20	230/16	230/18	230/19	225.0/16.7	LA
14	791126	900.40	1.1[illegible]	230/25	230/18	230/18	230/17	227.0/18.8	LA
15	791126	902.40	1.20	230/2[illegible]	230/21	230/20	230/21	232.0/20.0	LA
16	791126	904.43	1.23	230/20	230/19	230/20	230/20	217.0/19.1	LA
17	791126	907.05	1.30	230/20	230/19	230/19	230/18	227.0/13.5	LA
18	791126	908.44	0.[illegible]	230/23	240/14	240/13	230/13	232.0/19.9	LA
19	791126	911.03	1.3[illegible]	220/23	230/17	230/17	230/17	230.0/14.7	LA
20	791126	913.0[illegible]	1.1[illegible]	230/1[illegible]	230/18	230/19	230/19	230.0/16.6	LA
21	791126	915.01	1.2[illegible]	230/2[illegible]	230/18	230/19	230/22	224.0/21.1	LA
22	791126	916.20	0.5[illegible]	230/20	230/22	220/23	220/24	236.0/18.4	LA
23	791126	918.[illegible]	1.47	230/1[illegible]	230/18	230/17	230/18	232.0/17.1	LA
24	791126	921.29	1.14	230/20	220/21	230/23	220/24	223.0/18.6	LA
25	791126	923.25	0.[illegible]	230/20	220/19	230/1[illegible]	230/17	210.0/14.3	LA
26	791126	925.2[illegible]	1.0[illegible]	230/1[illegible]	220/17	230/19	230/20	231.0/20.1	LA
27	791126	927.19	1.17	230/2[illegible]	230/[illegible]	230/20	230/19	229.0/14.5	LA
28	791126	929.57	0.59	230/20	230/15	230/15	230/16	227.0/17.6	LA
29	791126	931.45	1.13	240/20	230/15	230/16	230/13	239.0/13.3	LA
30	791126	933.37	1.2[illegible]	230/15	240/14	240/14	240/15	227.0/14.4	LA
31	791126	935.44	1.1[illegible]	230/2[illegible]	230/15	230/16	230/16	229.0/17.3	LA
32	791126	937.5[illegible]	0.[illegible]	220/20	230/16	240/15	240/14	241.0/13.6	LA
33	791126	941.47	0.4[illegible]	230/15	240/17	240/1[illegible]	230/15	234.0/14.1	LA
34	791126	945.21	2.06	230/20	230/16	230/17	230/17	241.0/15.5	LA
35	791126	947.20	1.2[illegible]	230/24	230/15	230/16	230/16	229.0/20.2	LA
36	791126	949.50	1.57	230/15	230/20	230/19	230/17	230.0/17.9	LA
37	791126	952.55	2.41	230/15	230/16	230/17	230/18	228.0/12.1	LA
38	791126	954.27	1.02	230/20	230/13	230/12	230/12	230.0/13.9	LA
39	791126	956.09	0.56	230/20	230/12	230/13	230/13	228.0/16.4	LA
40	791126	959.23	1.15	220/23	230/15	230/15	230/14	223.0/15.5	LA
41	791126	1000.49	0.47	210/25	230/16	230/16	240/16	229.0/20.4	LA
42	791126	1002.33	1.10	220/25	230/19	230/19	220/18	221.0/19.7	LA
43	791126	1004.28	2.10	220/20	220/19	220/19	220/20	223.0/22.0	LA
44	791126	1006.29	1.27	230/25	220/20	220/20	220/19	227.0/16.3	LA
45	791126	1008.32	1.22	230/28	230/18	230/16	230/16	225.0/19.6	LA
46	791126	1010.20	1.0[illegible]	230/22	230/21	230/22	240/21	227.0/19.5	LA
47	791126	1012.22	1.15	210/20	230/19	230/18	230/16	218.0/17.8	LA
48	791126	1015.46	1.21	210/20	210/17	210/20	210/21	217.0/19.0	LA
49	791126	1018.35	1.4[illegible]	200/22	220/16	220/15	220/14	209.0/20.7	LA
50	791126	1020.00	0.53	230/20	210/21	210/21	210/21	213.0/22.8	LA

DATE	TIME	LAG	ATC	2-MIN	1-MIN	30-SEC	ACTUAL	

[illegible] ATC WIND - [illegible] STUDY [illegible] DATE/TIME: [illegible]

BASIC STATISTICS OF DIFFERENCES

	ATC WIND	2-MIN WIND	1-MIN WIND	30-SEC WIND
MEAN DIFFERENCE	4.5	3.2	3.3	3.5 KT
S.D. OF DIFFERENCE	3.[illegible]	1.5	1.7	2.1 KT

DISTRIBUTIONS OF WIND DIFFERENCES (OR ERRORS)

MAGNITUDE OF VECTOR ERROR (KT)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ATC	0	4	3	13	6	4	4	6	3	6	1	0	0	0	0	0	0	0	0	0	0
2-MIN	0	1	10	14	10	7	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0
1-MIN	0	1	9	11	11	9	2	3	2	0	0	0	0	0	0	0	0	0	0	0	0
30-SEC	0	4	9	10	9	7	4	3	3	1	0	0	0	0	0	0	0	0	0	0	0

ALONG-RUNWAY WIND COMPONENT ERROR (KT)

	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
ATC	0	0	0	0	0	0	0	0	3	3	2	6	4	7	6	2	5	5	3	3	1	0
2-MIN	0	0	0	0	2	1	2	4	4	5	6	3	7	9	3	1	3	0	0	0	0	0
1-MIN	0	0	0	1	2	1	2	4	2	3	6	6	5	6	3	4	3	0	0	0	0	0
30-SEC	0	0	0	1	3	1	1	3	1	8	8	6	3	6	2	3	3	1	0	0	0	0

ACROSS-RUNWAY WIND COMPONENT ERROR (KT)

	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
ATC	0	0	0	0	1	2	1	0	6	10	5	11	7	5	1	0	0	0	1	0	0	0
2-MIN	0	0	0	0	0	0	2	2	4	9	11	8	8	5	1	0	0	0	0	0	0	0
1-MIN	0	0	0	0	0	0	2	3	4	9	10	9	8	4	0	0	1	0	0	0	0	0
30-SEC	0	0	0	0	0	1	4	3	3	5	10	12	5	5	0	1	1	0	0	0	0	0

VECTOR MEAN WIND 228.3/ 17.2KT. STANDARD VECTOR DEVIATION 3.5KT.

MEAN WIND SPEED 17.5KT. COMPONENT MEAN -11.5KT (NS) -12.8KT (EW)

COMPONENT S.D. 2.7KT (NS) 2.2KT (EW)

	DATE	TIME	LAG	ATC	2-MIN	1-MIN	30-SEC	ACTUAL	
1	791205	1002.17	1.00	220/25	210/20	210/21	210/21	221.0/20.2	LAND
2	791205	1005.18	2.01	220/23	220/23	210/24	210/22	221.0/21.1	LAND
3	791205	1006.41	0.36	210/25	220/23	220/23	220/22	219.0/21.2	LAND
4	791205	1008.13	0.42	190/25	220/21	210/20	210/19	210.0/17.3	LAND
5	791205	1009.35	0.32	210/25	210/19	210/20	210/21	214.0/19.2	LAND
6	791205	1011.19	0.30	220/25	220/20	220/19	230/18	220.0/19.0	LAND
7	791205	1011.58	1.26	210/25	220/20	220/19	230/18	220.0/18.9	LAND
8	791205	1013.57	0.43	220/25	220/19	220/19	220/18	217.0/18.9	LAND
9	791205	1017.01	1.07	230/20	220/21	220/20	220/22	218.0/18.2	LAND
10	791205	1020.02	1.12	220/20	220/18	220/19	220/18	215.0/15.4	LAND
11	791205	1021.11	0.31	220/25	220/17	210/17	210/18	220.0/20.2	LAND
12	791205	1022.37	0.39	230/25	220/18	220/17	220/16	215.0/19.2	LAND
13	791205	1024.42	1.09	210/25	210/18	210/19	220/18	216.0/20.4	LAND
14	791205	1027.27	1.40	230/20	220/20	220/19	220/19	219.0/21.6	LAND
15	791205	1030.16	2.12	210/25	220/20	220/20	220/18	221.0/17.1	LAND
16	791205	1032.39	1.59	210/22	220/16	220/16	220/17	218.0/15.0	LAND
17	791205	1034.43	1.28	220/18	220/16	220/17	220/17	214.0/16.5	LAND
18	791205	1037.15	1.58	220/18	220/17	230/18	230/19	220.0/17.9	LAND
19	791205	1040.00	1.55	220/22	220/18	220/18	220/18	223.0/20.0	LAND
20	791205	1041.10	0.36	220/18	220/19	220/18	220/16	223.0/17.8	LAND
21	791205	1043.55	1.28	220/24	220/17	210/16	210/18	217.0/21.5	LAND
22	791205	1047.38	2.23	230/20	220/18	220/17	220/17	222.0/19.2	LAND
23	791205	1050.37	1.59	220/25	220/21	220/22	220/21	227.0/20.9	LAND
24	791205	1052.04	0.41	220/18	220/16	220/16	220/16	220.0/15.6	LAND
25	791205	1053.33	0.50	220/15	220/16	220/16	220/16	222.0/13.4	LAND
26	791205	1054.40	0.30	220/22	220/14	220/14	210/14	222.0/19.9	LAND
27	791205	1058.02	1.14	200/18	220/15	220/14	220/15	219.0/14.1	LAND
28	791205	1059.10	0.34	210/23	220/14	220/14	220/15	210.0/18.4	LAND
29	791205	1101.27	0.53	220/22	210/18	210/17	210/19	213.0/19.0	LAND
30	791205	1103.00	0.45	210/20	210/17	210/16	210/16	213.0/15.7	LAND
31	791205	1106.35	1.53	210/20	210/18	220/18	220/18	211.0/16.6	LAND
32	791205	1108.19	1.22	220/22	220/18	210/18	220/18	217.0/16.5	LAND
33	791205	1111.10	1.25	210/20	220/15	220/15	220/18	211.0/16.4	LAND
34	791205	1113.33	1.51	210/22	220/17	210/16	210/16	216.0/20.1	LAND
35	791205	1116.21	1.53	220/25	220/18	220/17	220/17	227.0/16.1	LAND
36	791205	1118.10	1.03	230/20	220/16	220/17	210/18	215.0/18.2	LAND
37	791205	1120.52	2.00	210/22	220/17	220/15	220/14	224.0/17.2	LAND
38	791205	1122.48	1.18	220/20	220/17	220/16	220/15	225.0/15.6	LAND
39	791205	1125.37	2.10	230/23	220/16	220/17	220/18	210.0/18.6	LAND
40	791205	1126.33	0.30	220/22	220/19	210/19	210/19	215.0/20.5	LAND
41	791205	1129.52	2.07	210/20	210/19	210/19	210/17	218.0/13.0	LAND
42	791205	1131.52	1.14	230/22	220/16	220/15	220/17	223.0/14.6	LAND
43	791205	1133.46	1.17	230/20	220/17	220/15	220/15	221.0/14.3	LAND
44	791205	1135.27	0.48	230/22	220/15	220/14	220/14	216.0/16.9	LAND
45	791205	1137.10	1.06	220/25	220/16	220/16	220/15	220.0/18.3	LAND
46	791205	1138.13	0.35	220/20	220/17	220/16	230/14	216.0/15.4	LAND
47	791205	1140.37	1.42	230/25	220/16	220/17	220/16	213.0/17.9	LAND
48	791205	1144.37	1.29	230/22	220/16	220/17	220/17	222.0/14.4	LAND
49	791205	1147.35	1.36	230/20	220/17	220/18	220/18	230.0/17.3	LAND
50	791205	1149.23	1.11	230/20	220/16	230/17	230/17	219.0/15.4	LAND

	DATE	TIME	LAG	ATC	2-MIN	1-MIN	30-SEC	ACTUAL

HEATHROW ATC WINDS - CASE STUDY 5 DATE/TIME: 05/12/79 1000-1150 GMT

BASIC STATISTICS OF DIFFERENCES

	ATC WIND	2-MIN WIND	1-MIN WIND	30-SEC WIND
MEAN DIFFERENCE	5.1	2.5	2.6	2.8 KT
S.D. OF DIFFERENCE	2.5	1.5	1.5	1.4 KT

DISTRIBUTIONS OF WIND DIFFERENCES (OR ERRORS)

MAGNITUDE OF VECTOR ERROR (KT)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ATC	0	2	4	8	3	8	6	7	5	4	2	1	0	0	0	0	0	0	0	0	0
2-MIN	0	6	17	14	7	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1-MIN	0	7	8	21	6	4	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
30-SEC	0	5	8	16	13	6	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0

ALONG-RUNWAY WIND COMPONENT ERROR (KT)

	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
ATC	0	0	0	0	0	0	0	0	0	2	0	4	8	5	3	13	6	3	4	2	0
2-MIN	0	0	0	0	1	1	2	2	4	8	8	4	11	6	1	1	1	0	0	0	0
1-MIN	0	0	0	0	0	2	2	2	8	5	6	12	5	6	1	0	1	0	0	0	0
30-SEC	0	0	0	0	1	1	1	5	6	7	6	10	6	5	1	1	0	0	0	0	0

ACROSS-RUNWAY WIND COMPONENT ERROR (KT)

	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
ATC	0	0	0	1	1	2	1	4	3	4	4	12	4	4	3	3	1	2	0	0	1
2-MIN	0	0	0	0	0	0	0	2	3	9	11	15	5	2	3	0	0	0	0	0	0
1-MIN	0	0	0	0	0	0	0	4	3	6	8	14	8	3	3	1	0	0	0	0	0
30-SEC	0	0	0	0	0	0	0	7	3	5	8	12	8	3	3	1	0	0	0	0	0

VECTOR MEAN WIND 218.7/ 18.0KT. STANDARD VECTOR DEVIATION 3.0KT.

MEAN WIND SPEED 18.2KT. COMPONENT MEAN -14.1KT (NS) -11.3KT (EW)

COMPONENT S.D. 2.3KT (NS) 1.9KT (EW)

	DATE	TIME	LAG	ATC	2-MIN	1-MIN	30-SEC	ACTUAL	
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	LAND
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	LAND
3	791209	[illegible]	1.11	200/25	190/21	190/22	190/22	[illegible]	T/O
4	[illegible]	[illegible]	[illegible]	190/28	190/[illegible]	190/22	190/21	[illegible]	LAND
5	791209	[illegible]	[illegible]	200/21	190/[illegible]	200/22	[illegible]/21	[illegible]	T/O
6	791209	1911.54	[illegible]	200/22	200/22	200/20	200/19	196.0/19.7	T/O
7	791209	1912.59	1.11	190/20	200/[illegible]	200/21	200/20	199.0/18.5	LAND
8	791209	1913.40	1.[illegible]	200/25	200/19	200/19	200/19	211.0/21.0	T/O
9	791209	1915.20	1.14	210/35	200/27	200/29	200/30	206.0/25.2	T/O
10	791209	1919.30	[illegible]	200/21	210/28	210/28	210/25	206.0/28.1	T/O
11	791209	1921.59	1.19	200/28	210/24	200/23	200/21	206.0/26.2	T/O
12	791209	1924.24	1.1[illegible]	200/26	200/24	210/22	210/22	201.0/[illegible]	T/O
13	791209	1925.40	2.22	200/28	200/23	200/22	200/22	205.0/29.2	LAND
14	791209	1926.25	1.01	200/30	200/28	200/29	200/28	205.0/29.1	T/O
15	791209	1927.34	[illegible]	200/26	200/29	200/29	200/29	201.0/26.9	LAND
16	791209	1929.29	1.3[illegible]	210/28	210/28	200/25	200/23	206.0/25.9	T/O
17	791209	1929.53	0.53	210/30	200/25	210/25	210/26	208.0/26.9	LAND
18	791209	1932.28	1.06	200/25	210/26	210/27	210/30	206.0/30.1	T/O
19	791209	1934.53	1.[illegible]	200/30	210/27	210/27	210/26	208.0/24.6	LAND
20	791209	1935.20	[illegible]	200/26	210/27	210/27	210/26	204.0/25.1	T/O
21	791209	1936.57	[illegible]	210/30	210/26	210/27	210/29	210.0/25.0	LAND
22	791209	1939.09	1.[illegible]	200/28	210/26	210/25	200/27	213.0/23.2	T/O
23	791209	1939.14	1.17	210/30	210/26	210/25	200/27	213.0/23.2	LAND
24	791209	1941.33	1.34	220/28	210/29	220/30	230/27	232.0/21.4	LAND
25	791209	1941.43	1.[illegible]	220/24	220/26	230/25	230/23	232.0/21.4	T/O
26	791209	1943.33	[illegible]	220/40	220/30	220/36	220/38	225.0/42.5	LAND
27	791209	1945.48	[illegible]	220/25	230/40	230/41	240/36	243.0/30.4	LAND
28	791209	1947.46	0.54	250/28	250/[illegible]	250/28	250/28	262.0/27.6	LAND
29	791209	1949.08	1.06	250/28	260/26	260/25	260/28	258.0/24.7	T/O
30	791209	1950.47	1.32	250/25	260/25	260/24	260/23	265.0/21.9	LAND
31	791209	1952.01	1.[illegible]	260/22	260/24	260/25	260/22	274.0/21.3	T/O
32	791209	1954.28	2.[illegible]	250/30	270/22	270/22	260/23	273.0/22.8	LAND
33	791209	1955.51	[illegible]	260/25	260/21	270/22	270/21	268.0/21.9	LAND
34	791209	2007.52	1.42	250/15	260/15	260/15	260/16	260.0/13.8	T/O
35	791209	2008.43	1.29	250/15	260/14	250/12	260/13	261.0/16.5	T/O
36	791209	2028.46	1.48	230/20	250/18	250/16	250/15	251.0/12.8	LAND
37	791209	2031.05	0.30	250/22	250/13	240/12	240/12	246.0/12.0	LAND
38	791209	2033.41	1.19	250/20	250/16	250/17	250/19	250.0/15.6	T/O
39	791209	2035.10	2.49	250/20	250/16	250/17	250/19	252.0/13.0	LAND
40	791209	2037.19	1.59	230/18	250/14	250/14	240/15	241.0/10.7	T/O
41	791209	2039.15	1.44	230/15	240/14	240/12	240/11	236.0/14.3	LAND
42	791209	2042.20	1.18	240/18	250/14	250/14	250/14	240.0/16.0	T/O
43	791209	2043.45	1.19	240/22	240/16	240/16	240/16	238.0/14.1	T/O
44	791209	2045.00	1.59	230/20	240/16	240/15	240/13	250.0/11.9	LAND
45	791209	2045.23	1.34	240/16	240/15	240/16	240/14	241.0/14.0	T/O
46	791209	2048.28	1.20	230/18	240/16	240/15	230/14	235.0/17.6	T/O
47	791209	2051.19	1.41	240/15	240/16	240/15	250/18	230.0/17.2	LAND
48	791209	2051.28	0.43	230/18	250/19	250/19	240/20	230.0/17.2	T/O

DATE TIME LAG ATC 2-MIN 1-MIN 30-SEC ACTUAL

TABLE 6

HEATHROW ATC WINDS - CASE STUDY 1 DATE/TIME: ../11/.. 1[illegible] - [illegible] GMT

BASIC STATISTICS OF DIFFERENCES

	ATC WIND	2-MIN WIND	1-MIN WIND	30-SEC WIND
MEAN DIFFERENCE	5.1	3.9	3.7	3.9 KT
S.D. OF DIFFERENCE	3.1	2.8	2.5	[illegible] KT

DISTRIBUTIONS OF WIND DIFFERENCES (OR ERRORS)

MAGNITUDE OF VECTOR ERROR (KT)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ATC	0	1	6	9	7	5	4	2	5	1	2	3	0	2	0	0	0	0	0	0	0
2-MIN	0	1	9	10	11	5	3	6	0	0	0	0	0	3	0	0	0	0	0	0	0
1-MIN	0	2	7	15	10	4	2	2	4	0	0	1	0	0	1	0	0	0	0	0	0
30-SEC	0	2	6	10	9	5	9	4	2	1	0	0	0	0	0	0	0	0	0	0	0

ALONG-RUNWAY WIND COMPONENT ERROR (KT)

	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
ATC	0	0	0	0	0	0	0	3	6	0	4	3	5	4	2	6	0	6	1	0	1	1
2-MIN	1	0	0	0	1	0	2	0	3	3	5	10	8	6	4	2	0	1	1	0	0	1
1-MIN	0	0	0	0	1	1	1	1	4	4	7	0	11	3	5	1	0	1	0	1	0	1
30-SEC	0	0	0	0	0	0	3	4	3	4	4	9	5	4	7	1	3	0	1	0	0	0

ACROSS-RUNWAY WIND COMPONENT ERROR (KT)

	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
ATC	0	0	0	0	0	0	0	1	1	1	4	3	11	8	5	3	3	3	1	3	0	1
2-MIN	0	0	0	0	0	0	4	3	2	3	9	7	5	6	3	2	2	1	0	0	1	0
1-MIN	0	0	0	1	0	1	2	3	3	4	4	8	9	4	4	3	2	0	0	0	0	0
30-SEC	0	0	0	1	0	2	1	4	1	6	6	10	3	5	4	1	3	1	0	0	0	0

VECTOR MEAN WIND 227.1/ 17.9KT. STANDARD VECTOR DEVIATION 10.9KT.

MEAN WIND SPEED 20.0KT. COMPONENT MEAN -12.2KT (NS) -13.1KT (EW)

COMPONENT S.D. 9.3KT (NS) 5.6KT (EW)

TABLE 7

Summary of errors in ATC, 2-min, 1-min and 30-sec winds for case studies 2-6 combined.

(percentages, out of a total of 248, given in parentheses)

	magnitude of vector error (kt)	
	> 5	> 10
ATC	119 (48.0)	18 (7.3)
2-min	57 (23.0)	3 (1.2)
1-min	50 (20.2)	2 (0.8)
30-sec	67 (27.0)	1 (0.4)

	along-runway wind component error (kt)	
	< -5	> +5
ATC	13 (5.2)	58 (23.4)
2-min	15 (6.0)	11 (4.4)
1-min	16 (6.5)	13 (5.2)
30-sec	15 (6.0)	18 (7.3)

	across-runway wind component error (kt)	
	< -5	> +5
ATC	10 (4.0)	41 (16.5)
2-min	4 (1.6)	10 (4.0)
1-min	7 (2.8)	7 (2.8)
30-sec	6 (2.4)	11 (4.4)

FIG. 1. HEATHROW (NE-SITE) 1200–1300 GMT 9/8/79
WIND DIRECTION AND SPEED

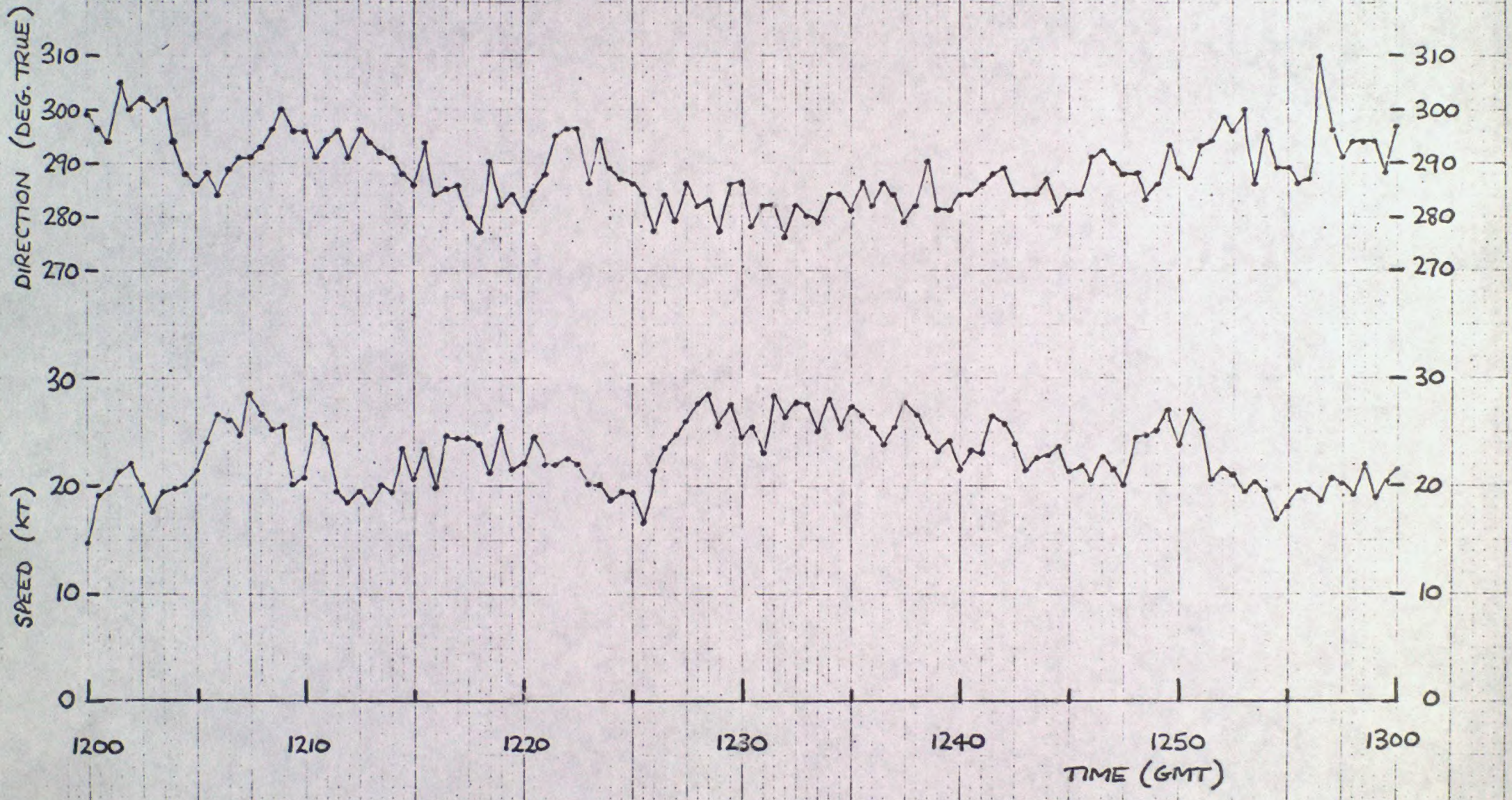
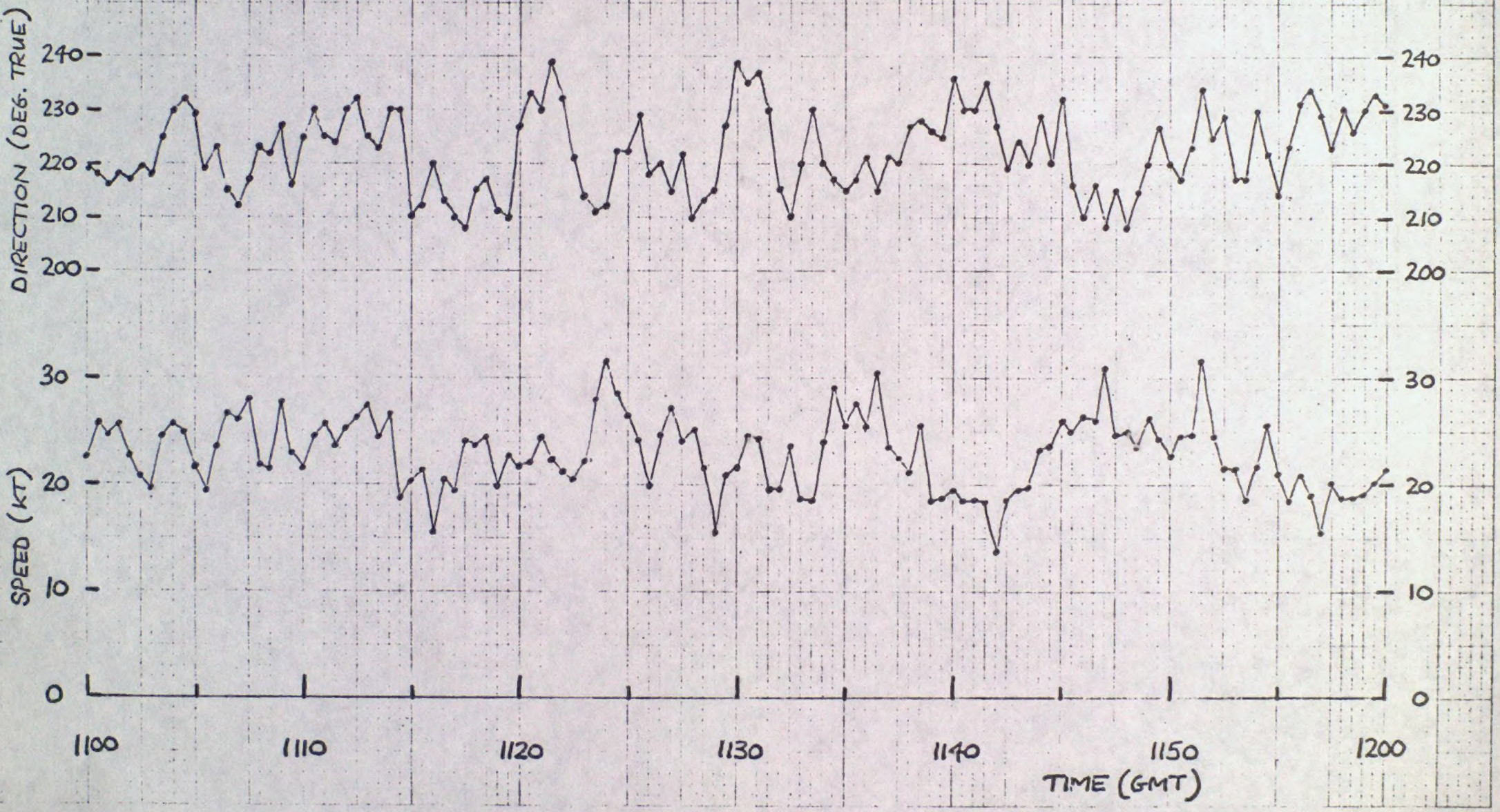


FIG. 2. HEATHROW (NE-SITE) 1100–1200 GMT 14/8/79
WIND DIRECTION AND SPEED



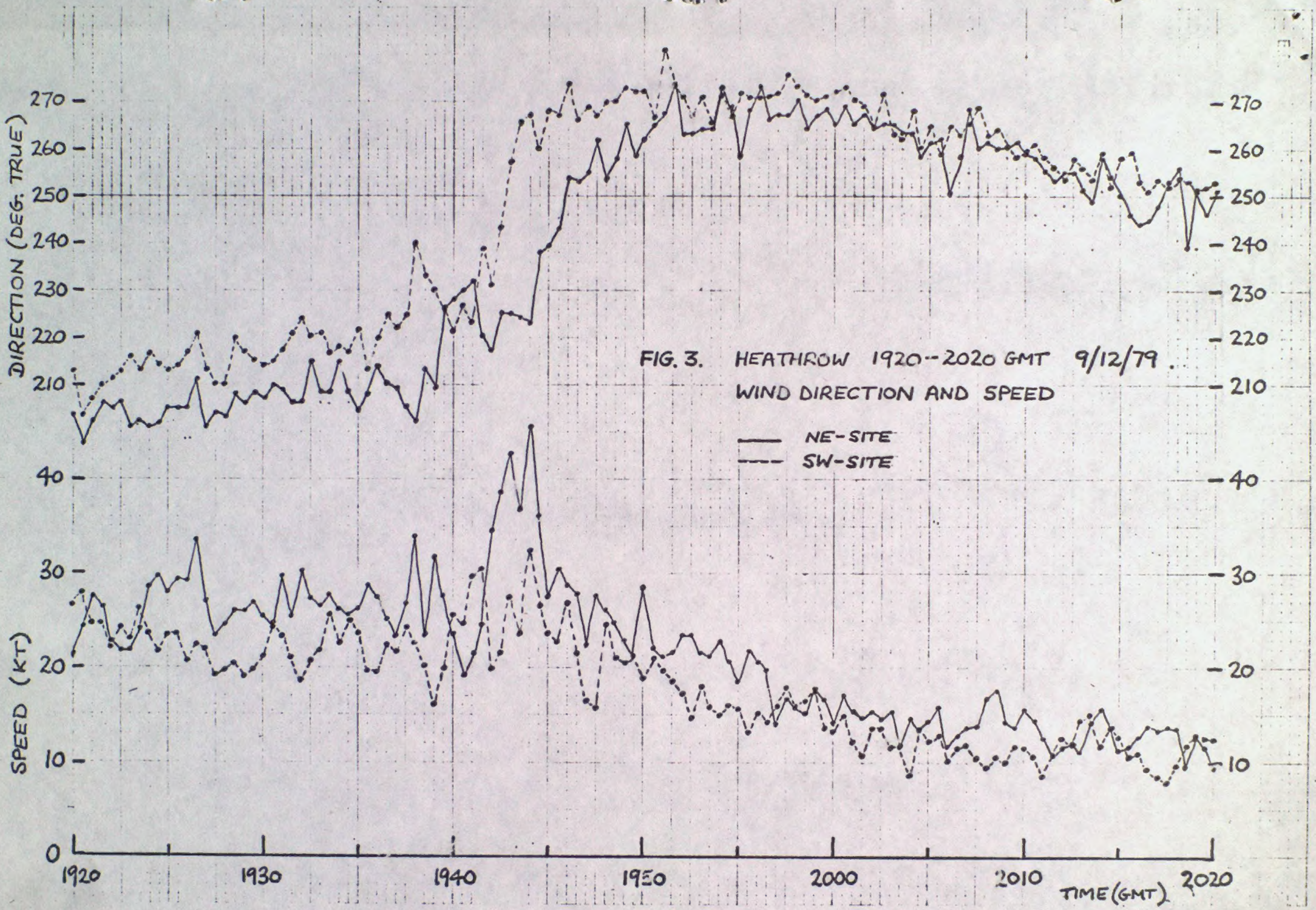


FIG. 3. HEATHROW 1920--2020 GMT 9/12/79
WIND DIRECTION AND SPEED